

**Solid-State Solar-Thermal Energy Conversion Center (S<sup>3</sup>TEC Center)**  
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**Lead Institution: Massachusetts Institute of Technology**

*Mission Statement:* S<sup>3</sup>TEC Center is to become an intellectual base to develop transformational solid-state solar-thermal to electric energy conversion technologies by advancing fundamental science of energy carrier coupling and transport, and to use the fundamental understanding to design new materials and devices to achieve a leapfrog in efficiency, to develop cost-effective manufacturing processes for energy conversion materials, devices, and systems, and along the way, to develop new interdisciplinary approaches for nano and energy workforce training, foster nano-energy based enterprises, and enhance the public awareness of the societal impacts of nanotechnology and engage them in energy conservation.

The S<sup>3</sup>TEC Center aims at advancing fundamental science and developing materials to harness heat from the sun and convert this heat into electricity via solid-state thermoelectric (Fig. 1a) and thermophotovoltaic (Fig.1b) technologies. Solar thermophotovoltaics (STPV) first use solar radiation to raise the temperature of a terrestrial object, which then emits photons optimized to the bandgap of a photovoltaic cell to generate electricity. Solar thermoelectric energy conversion uses solar radiation to create a temperature difference across a solid-state material to generate electricity. These technologies have transformative potentials: solar thermophotovoltaics have a theoretical maximum efficiency of 85% with a single junction photovoltaic cell, while solar thermoelectrics could potentially reduce solar electricity generation cost below \$0.5 per electrical watt ( $W_e$ ), compared to silicon based PV cells currently at \$3-4/ $W_e$ . Thermoelectrics can also be used in combination with current solar technologies. Both thermoelectric and thermophotovoltaic technologies can be applied to terrestrial heat sources, for example, geothermal, waste heat from industrial processes, transportation and buildings. Thermoelectric devices can also be used for refrigeration and air-conditioning without producing any greenhouse gases.

The efficiency of solar thermoelectric generators (STEG) depends on spectrally selective surfaces with a high absorbance to the solar radiation and a low emittance in the infrared range, and depends on the availability of thermoelectric materials with high figure of merit, which is linearly proportional to the electrical conductivity, the square of the Seebeck coefficient, and inversely proportional to the thermal conductivity. The S<sup>3</sup>TEC center aims at advancing

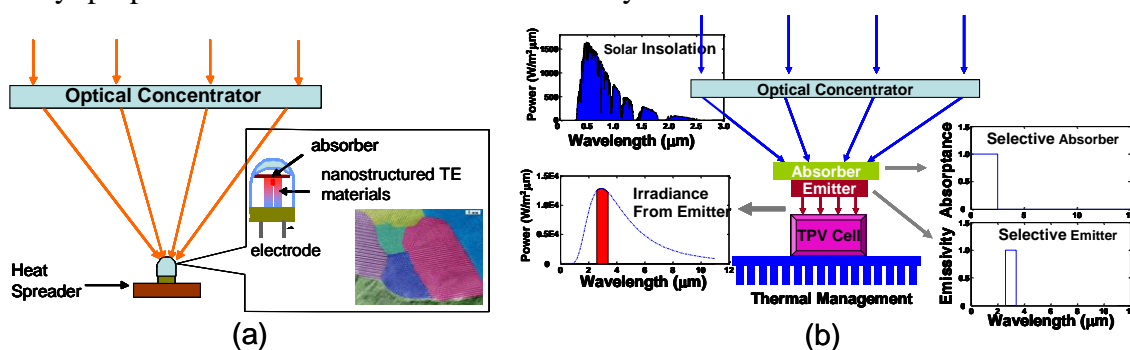


Figure 1 Solid-state solar-thermal energy conversion technologies to be pursued at the S<sup>3</sup>TEC Center (a) low-cost solar thermoelectric generators (STEGs) built from high performance nanostructured thermoelectric materials, and (b) high efficiency solar thermophotovoltaics achieved via precision spectral control.

thermoelectric materials through detailed experimental and theoretical studies of electron and phonon transport in nanostructures and bulk materials. Optical pump-probe and neutron scattering will be used to understand phonon transport, together with quantum and classical simulation of phonon transport in bulk and nanostructured materials. Electron spectroscopy will be performed in both thermoelectric materials and at the electrical contact regions, together with transport modeling. Both thin films and bulk nanostructures will be investigated, aiming at eventual large scale applications. Prototypes will be built to demonstrate the potential of the solar thermoelectric generation. Neutron spectrometers and STEM at Oak Ridge National Laboratory will be used for phonon spectroscopy and high-resolution imaging of interfacial structures. Ultraviolet photoelectron spectroscopy at Brookhaven National Laboratory (BNL) will be employed to measure the work function of the developed thermoelectric materials and contacting electrode materials.

Spectral control is not only important for STEG, but also crucial for STPV. Ideal selective absorbers should absorb all solar radiation, but not lose heat via their own thermal emission. In a solar TPV, broadband solar insolation is first absorbed by a surface, which heats the absorber to 1000-2000 °C. On the other side of the absorber is an emitter, which reradiates photons that are optimized to match a photovoltaic cell. The maximum efficiency of such solar TPV converters is 85.4%, very close to that of multijunction cells with an infinite number of stages (86.8%), but it can be achieved with a single junction cell. Selective surfaces for solar TPV are more challenging due to their higher operational temperature. Key questions for solar TPV are: (1) How we can push structure design to reach the theoretical limit for selective absorbers and emitters? (2) Will the structure be stable at operational temperature? (3) How we can achieve high performance selective surfaces at low cost. And (4) how can we deliver high photon flux in a narrow spectral band. Our proposed research includes selective absorber and emitter design, fabrication, testing, high temperature stability studies for both thermoelectric materials and spectral control structures, and solar TPV prototyping.

The S<sup>3</sup>TEC education/outreach initiatives will focus on training the next generation of energy science, technology, and entrepreneurship leaders; integrating research with education; attracting women and minority students into engineering and towards advanced engineering degrees, helping industry improve their energy efficiency, and creating new jobs.

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